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(54) **Aluminium alloy containing silicon for use as pistons in automobiles**

Al-Legierung mit Silizium für Kolben in Kraftfahrzeugen

Alliage d'aluminium avec silicium pour un piston dans une voiture

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- **PATENT ABSTRACTS OF JAPAN vol. 013, no. 331 (C-622), 25 July 1989 & JP 01 108339 A (TOYOTA MOTOR CORP), 25 April 1989**
- **PATENT ABSTRACTS OF JAPAN vol. 096, no. 011, 29 November 1996 & JP 08 176768 A (NISSAN MOTOR CO LTD), 9 July 1996**

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Description

[0001] The present invention relates to a aluminium-silicon alloy. The alloy has use in the manufacture of pistons, in particular for pistons for use in internal combustion engines.

[0002] A satisfactory piston material must meet many differing requirements. In use, pistons are exposed to both static and dynamic stresses, while operating in bulk temperatures from sub-zero to up to 400°C. These stresses will also differ in different regions of the piston; for example a combustion bowl in a piston will be subject to different thermal and mechanical stresses than piston pin bosses. The piston must also have low thermal expansion, and possess good bearing characteristics with marginal lubrication over the noted range of temperatures. Also, the piston material must lend itself to being formed into a piston, for example by casting with subsequent working.

[0003] Known casting alloys for piston manufacture include those disclosed in Japanese Patent Application JP1108339-A. Among the alloys disclosed therein is an aluminium based alloy including silicon from 9 to 12 percent, copper from 0.5 to 2.5 percent, magnesium from 0.8 to 2.0 percent, cobalt from 0.5 to 3 percent, nickel from 1 to 3 percent, iron from 0.3 to 1.0 percent, manganese from 0.1 to 1.0 percent and titanium from 0.01 to 0.15 percent with the balance being aluminium and unavoidable impurities. This alloy is said to provide high strength from 150 to 250 °C.

[0004] Another alloy is disclosed in DE 44 04 420 which may have application as an alloy for use in the manufacture of pistons for an automotive vehicle. The alloy comprises from 8.0 to 10.9 percent silicon, from 0.8 to 2.0 percent magnesium, from 4.0 to 5.9 percent copper, from 1.0 to 3.0 percent nickel, from 0.2 to 0.4 percent manganese, less than 0.5 percent iron and at least one element from the group including antimony, zirconium, titanium, strontium, cobalt, chrome and vanadium whereby at least one element is present in an amount greater than 0.8 percent and the sum of the elements in this group is no more than 0.8 percent, with the balance of the alloy being aluminium and unavoidable impurities.

[0005] The present invention has as an advantage that it provides good strength over the range of temperatures in which a piston made from the alloy operates.

[0006] The alloy of the present invention is selected from a group of aluminium alloys with each alloy component element being present in weight percent as follows:

10.5 to 13.5 silicon
2.0 to less than 4.0 copper
0.8 to 1.5 magnesium
0.5 to 2.0 nickel
0.3 to 0.9 cobalt
at least 20 ppm phosphorous

and either

- (i) 0.05 to 0.2 titanium; or
- (ii) at least one of the following

up to 0.2 zirconium
up to 0.2 vanadium;
in either case with the balance Aluminium and unavoidable impurities.

[0007] Preferably Zinc, Lead and Tin may also be present up to 0.15 weight percent. More preferably, the total amount of Lead and Tin may not exceed 0.15 weight percent.

[0008] The Copper allows age hardening of the alloy. An increase the amount of Copper beyond the limit stated reduces the high temperature fatigue strength of the alloy due to the generation of larger Copper-Nickel rich intermetallic crystals. An increase in the Copper level can also lead to shrinkage porosity problems in larger castings.

[0009] The Magnesium is present to contribute to the strength of the alloy. However, increasing the amount of Magnesium will lead to larger intermetallics in the as cast condition, but after aging these will be removed. The Magnesium is added at a level where it provides good strengthening after aging through the formation of Mg₂Si. Higher Magnesium levels lead to greater oxidation losses during the casting process, and thus a greater tendency for the cast metal to contain oxide defects.

[0010] The Nickel contributes to the high temperature strength of the alloy by the formation of thermally stable intermetallic crystals. However, exceeding the limits stated will reduce the high temperature fatigue strength of the alloy due to the precipitation of coarse intermetallic crystals. This tendency is made worse by the low cooling rates associated with the casting of large pistons.

[0011] The Cobalt content is chosen to allow the formation of a large number of small intermetallics. This is believed to improve the mechanical properties of the alloy at 350°C. In addition, the presence of the Cobalt in the Aluminium alloy at the levels stated is believed to reduce the diffusivity of the Copper in Aluminium, thereby slowing the overaging mechanism of the alloy. This has particular importance when considering the operation of a piston pin boss operating at around 200°C. However, the presence of the Cobalt is believed also to lead to an increase in fatigue strength of the alloy at 350°C. This is of particular importance when considering the operation of a combustion bowl of a piston which is typically subject to such temperatures.

[0012] The Titanium or Zirconium and/or Vanadium are each present as a grain refining addition.

[0013] Preferably, the alloy may at the expense of aluminium optionally include at least one of the following

up to 0.5 iron

up to 0.25 manganese
up to 0.05 chrome, and
up to 15 ppm each of calcium, sodium, strontium
and lithium.

[0014] The present invention will now be described,
by way of example only, with reference to the following
Illustrative Examples.

Example 1

[0015] The use of a specific alloy composition in the
manufacture of forged pistons has proven to be partic-
ularly advantageous. The metal alloy compositions of
this alloy with the component elements being indicated
in weight percent are as follows:

10.5 to 13.5 silicon
2.0 to less than 4.0 copper
0.8 to 1.5 magnesium
0.5 to 2.0 nickel
0.3 to 0.9 cobalt
0.05 to 0.2 titanium
at least 20 ppm phosphorous
with the balance Aluminium and unavoidable impu-
rities.

Example 2

[0016] Another alloy within the scope of the present
invention also found to have utility in the manufacture of
pistons has the following composition with the compo-
nent elements being indicated in weight percent as fol-
lows:

10.5 to 13.5 silicon
2.0 to less than 4.0 copper
0.8 to 1.5 magnesium
0.5 to 2.0 nickel
0.3 to 0.9 cobalt
at least 20 ppm phosphorous; and
at least one of the following
up to 0.2 zirconium
up to 0.2 vanadium;
with the balance Aluminium and unavoidable impu-
rities.

Example 3

[0017] Another alloy within the scope of the present
invention found to have utility in the manufacture of pis-
tons has the following composition with the component
elements being indicated in weight percent as follows:

10.5 to 11.5 silicon
2.5 to 3.5 copper
0.8 to 1.5 magnesium
0.5 to 1.5 nickel

0.3 to 0.7 cobalt
0.05 to 0.20 titanium
up to 0.2 zirconium
up to 0.2 vanadium
up to 0.50 iron
up to 0.25 manganese
up to 0.05 chrome
up to 0.15 zinc
up to 0.15 lead
up to 0.15 tin; the total of lead and tin not to exceed
0.15
at least 20 ppm phosphorous
up to 15 ppm each of calcium, sodium, strontium
and lithium
with the balance Aluminium and unavoidable impu-
rities

[0018] The alloys of the present invention, in addition
to their use in the manufacture of forged pistons, may
be used in the manufacture of gravity die cast pistons.

Claims

1. An aluminium alloy in which the component ele-
ments are present in weight percent as follows:

10.5 to 13.5 silicon
2.0 to less than 4.0 copper
0.8 to 1.5 magnesium
0.5 to 2.0 nickel
0.3 to 0.9 cobalt
at least 20 ppm phosphorous
and either

(i) 0.05 to 0.2 titanium; or
(ii) at least one of the following

up to 0.2 zirconium
up to 0.2 vanadium;
in either case with the balance Aluminium and
unavoidable impurities.

2. An alloy according to claim 1, characterised in that
Zinc, Lead and Tin may also be present up to 0.15
wt% as unavoidable impurities.

3. An alloy according to claim 2, characterised in that
the total amount of Lead and Tin does not exceed
0.15 wt%.

4. An alloy according to any of claims 1 to 3, charac-
terised in that the alloy, at the expense of alumin-
ium, may optionally include at least one of the fol-
lowing

up to 0.5 iron
up to 0.25 manganese

up to 0.05 chrome, and
up to 15 ppm each of calcium, sodium, strontium and lithium.

5. A piston manufactured from an alloy according to any previous claim.
6. A piston according to claim 5, characterised in that the piston is manufactured by forging.
7. A piston according to claim 5, characterised in that the piston is manufactured by gravity die casting.

Patentansprüche

1. Aluminiumlegierung, in welcher die Elementbestandteile in Gew.-% wie folgt vorliegen:

10,5 bis 13,5 Silicium
2,0 bis weniger als 4,0 Kupfer
0,8 bis 1,5 Magnesium
0,5 bis 2,0 Nickel
0,3 bis 0,9 Kobalt
wenigstens 20 ppm Phosphor
und entweder

- (i) 0,05 bis 0,2 Titan; oder
- (ii) wenigstens eines der folgenden

bis zu 0,2 Zirkon
bis zu 0,2 Vanadium;
in jedem Fall mit dem Rest Aluminium und unvermeidbaren Verunreinigungen.

2. Legierung nach Anspruch 1, dadurch gekennzeichnet, daß Zink, Blei und Zinn ebenfalls in bis zu 0,15 Gew.-% als unvermeidbare Verunreinigungen vorhanden sein können.
3. Legierung nach Anspruch 2, dadurch gekennzeichnet, daß die Gesamtmenge an Blei und Zinn 0,15 Gew.-% nicht übersteigt.
4. Legierung nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß die Legierung zu Lasten von Aluminium gegebenenfalls wenigstens eines der folgenden enthalten kann

bis zu 0,5 Eisen
bis zu 0,25 Mangan
bis zu 0,05 Chrom und
bis zu 15 ppm jeweils von Calcium, Natrium, Strontium und Lithium.
5. Kolben, hergestellt aus einer Legierung nach einem vorhergehenden Anspruch.

6. Kolben nach Anspruch 5, dadurch gekennzeichnet, daß der Kolben durch Schmieden hergestellt ist.

- 5 7. Kolben nach Anspruch 5, dadurch gekennzeichnet, daß der Kolben durch Dauerformguß hergestellt ist.

10 Revendications

1. Alliage d'aluminium dans lequel les éléments constitutifs sont présents en pourcentage en poids de la manière suivante :

silicium : 10,5 à 13,5
cuivre : 2,0 à moins de 4,0
magnésium : 0,8 à 1,5
nickel : 0,5 à 2,0
cobalt : 0,3 à 0,9
phosphore : au moins 20 ppm
et soit

- (i) titane : 0,05 à 0,2 ; soit
- (ii) au moins l'un des éléments suivants

zirconium : jusqu'à 0,2
vanadium : jusqu'à 0,2 ;
dans tous les cas avec le pourcentage restant constitué d'aluminium et d'impuretés inévitables.

2. Alliage suivant la revendication 1, caractérisé en ce que le zinc, le plomb et l'étain peuvent également être présents en une quantité allant jusqu'à 0,15 % en poids comme impuretés inévitables.
3. Alliage suivant la revendication 2, caractérisé en ce que la quantité totale de plomb et d'étain ne dépasse pas 0,15 % en poids.
4. Alliage suivant l'une quelconque des revendications 1 à 3, caractérisé en ce qu'il peut comprendre facultativement, aux dépens de l'aluminium, au moins l'un des éléments suivants

fer : jusqu'à 0,5
manganèse : jusqu'à 0,25
chrome : jusqu'à 0,05, et
calcium, sodium, strontium et lithium : chacun en une quantité allant jusqu'à 15 ppm.
5. Piston produit à partir d'un alliage suivant l'une quelconque des revendications précédentes.
6. Piston suivant la revendication 5, caractérisé en ce qu'il est produit par forgeage.

7. Piston suivant la revendication 5, caractérisé en ce qu'il est produit par coulée en coquille.

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